Air Quality and Health in the Greater Los Angeles Area: A Region in Crisis

Ed Avol

We are home to one of the world's most diverse populations, a veritable melting pot of cultures. We live in an area where our weather pattern is often described as "summer or not summer", where lifestyles of excess and poverty can be found within blocks of each other, and where winter is something "those folks back east" worry about. Our population and economy continue to grow in a region where almost half of the entire country's imports pass through our ports and over our roads and rail, where "freeways" and "rush hour" are increasingly oxymorons, and where – with a lot of hard work and determination – it will still take at least another decade to achieve federal air quality standards originally established almost 40 years ago to protect public health.

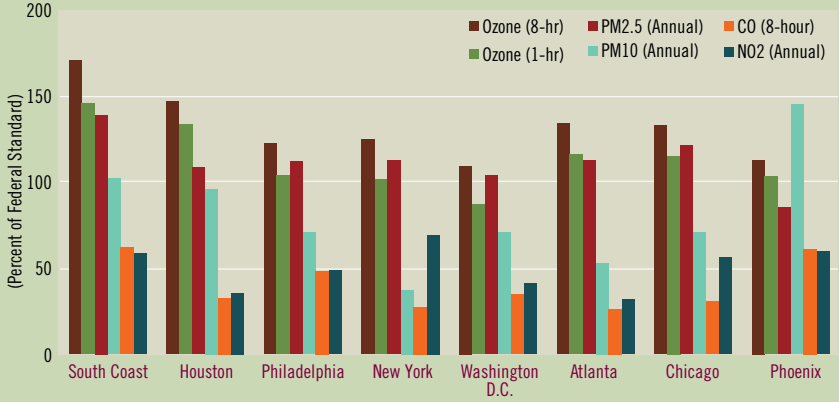
This year, local governments in the region (through the Southern California Association of Governments [SCAG]) passed a resolution asking that a state and federal emergency be declared to address the region's Air Quality/Health crisis[1]. Was this action supported by the available evidence? If so, what can be done, and what are we doing about it? With the push for economic growth, increased infrastructural development, and expanded goods movement activities in Southern California, where does public health fit into the discussion?

Understanding the Challenge

Southern California has been a perennial competitor for the dubious distinction of "poorest air quality in the nation". Ambient (outdoor) ozone and particulate levels have historically been among the highest in the country and continue to violate established National Ambient Air Quality Standards[2] (NAAQS) (See Figures 1 and 2). In the face of continued population growth, sprawling urbanization, increasing annual vehicle miles traveled, and expanding business activities, the regional air pollution regulatory control agencies (the State of California Air Resources Board [CARB] and the South Coast Air Quality Management District [SCAQMD]) have worked hard to develop emissions reduction strategies to reduce outdoor levels of airborne contaminants. Downward trends in annual outdoor concentrations of

Figure 1

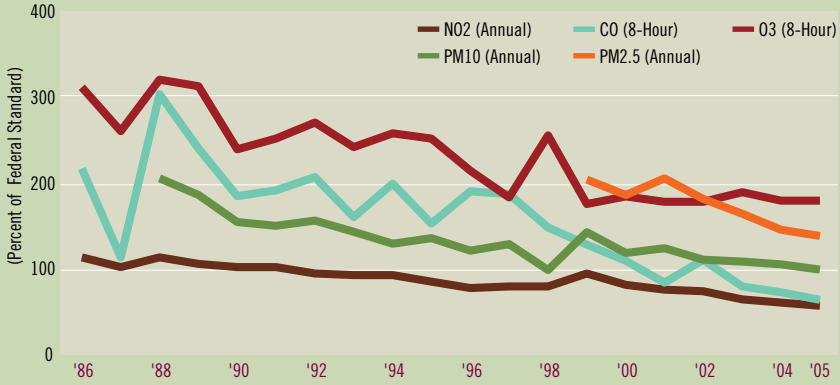
Maximum Pollutant Concentrations in the South Coast Air Basin Compared to Other U.S. Metro Areas, 2005



Source: South Coast Air Quality Management District

Figure 2

Maximum Pollutant Concentrations in the South Coast Air Basin



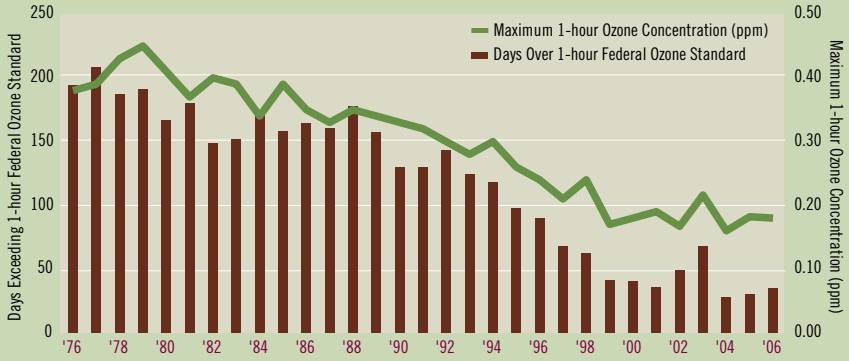
Source: South Coast Air Quality Management District and Air Resources Board, The California Almanac of Emissions and Air Quality - 2007 Edition

ozone (that clear photochemical gas that made LA smog a catchphrase) and particulate matter (microscopic pieces of dirt floating in the air each day) seem generally encouraging (see Figures 3 and 4). Recently, the steady annual improvement in air quality seems to have slowed, possibly due in part to decreasing effectiveness of control strategies, changes in regional meteorology, or increasing environmental pressures from a burgeoning population.

But even as we inch towards achieving the federal air standards developed to protect public health, the proverbial goal lines are moving. Recent reviews by the CARB and the US Environmental Protection Agency (EPA) have resulted in a tightening of both state and federal standards for oxides of nitrogen in California[3] and for ozone and particulate matter in California and the US[4-5, 6-7]. EPA is currently reviewing the federal oxides of nitrogen (NOx) standard, and the EPA Administrator is considering lowering the ozone standard, following a strong recommendation to do so from the EPA Clean Air Science Advisory Committee[8]. Under existing standards, compliance

Figure 3

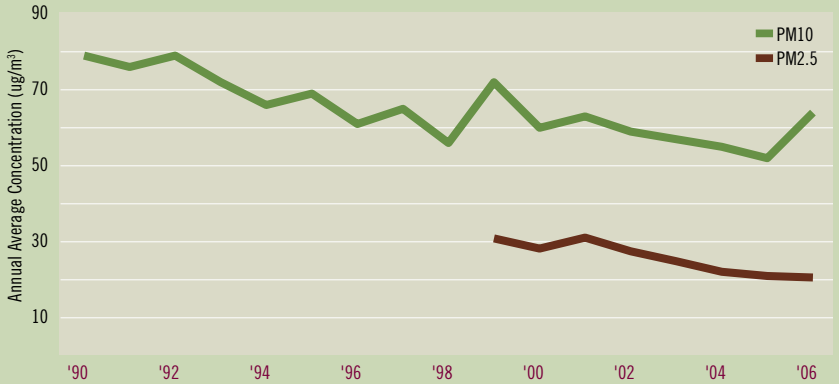
Ozone Trends in the South Coast Air Basin



Source: South Coast Air Quality Management District

Figure 4

PM_{10} and $PM_{2.5}$ Trends in the South Coast Air Basin



Source: South Coast Air Quality Management District

dates in the Southern California region ("compliance" being defined as having air to breathe in this Basin that meets the federal standards for acceptable air quality) are presently 2014 for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) and 2024 for ozone[9]. These far-off dates are both troubling and discouraging, and seem to represent a resigned acceptance of another decade or more of continued intentional exposure for millions of residents to unhealthy air.

So what does the current health data show? Is there truly a health crisis?

What the Health Data Show

Air quality standards are based on published scientific data relevant to the contaminant under review. Thousands of published articles have documented the health effects of the nationally-recognized "criteria" pollutants (ozone, particulate matter (PM), NOx, sulfur oxides (SOx), carbon monoxide, and lead). It is beyond the scope of this essay

to quantify the known information about the criteria pollutants. However, a brief summary of relevant recent health findings will demonstrate the current level of understanding regarding continued exposure to outdoor pollution.

Morbidity

In recent years, a growing body of research has become available relating both lung function level and growth rate to long-term air pollution exposure. Decreased lung growth rates, decreased lung function performance (the measurable ability to move air through the airways), and increased respiratory symptoms in children growing up in Southern California communities with higher levels of NOx and PM have been reported[10-13]. Similar findings have been observed in other populations of children exposed to vehicle combustion exhaust (which contains both gases and particulates)[14,15]. For children growing up in Southern California communities impacted by ambient ozone, studies have reported increased asthma[16] and respiratory illnesses leading to more school absences, lost learning time, and considerable economic burden[17,18]. The cumulative impact of these respiratory effects can be life-long degradation of health, since low lung function and symptoms are predictors of later-life respiratory disease and mortality[19-22].

Additional health investigations have suggested that proximity to busy roadways and traffic (a key source of PM in Southern California) plays an important role in children's respiratory health development. Decreased lung function and increased risk for asthma are associated with living near busy roads[23,24]. Busy roads and traffic have also been associated with increased risks for low birth weights, pre-term births, and even infant death[25-27].

The recent interest in the effects of particulate exposure on human health has resulted in a number of studies linking long-term PM exposures to several cardiovascular (heart-related) endpoints[28-30]. Mechanistically, studies have demonstrated how ultra-fine particles (particles smaller than 100 nanometers, or 1/600th of the diameter of a human hair) emitted from incomplete combustion of engine fuels and lubricating oils can bypass the body's defensive mechanisms, gain entry to cells and tissues, and alter or disrupt normal cellular function[31-33].

Mortality

Hundreds of research studies have addressed the association between ambient air pollution and human mortality[34]. Deaths in California[35-37],

the United States[38-41], and across the world[42,43] have been linked to air pollution exposure. CARB estimates that over 5400 premature deaths, 2400 hospitalizations, and almost a million lost work days are attributable each year to particulate pollution in the South Coast Air Basin (our regional area)[44]. Concerns about the possible confounding effects of specific modeling approaches, temperature, or other pollutants have led to a number of sensitivity analyses[45-47]. Although the precise magnitude of the risk or identification of the specific particulate constituent responsible may remain open questions, there is a growing consensus that air pollution is making us sick and killing us.

But as the data moves us closer to a clearer understanding of air pollution exposure and its adverse health effects, are there counter-balancing societal pressures that explain, account for, or potentially justify these increased risks?

Urban Pressures Affecting the Air Quality/Health Connection

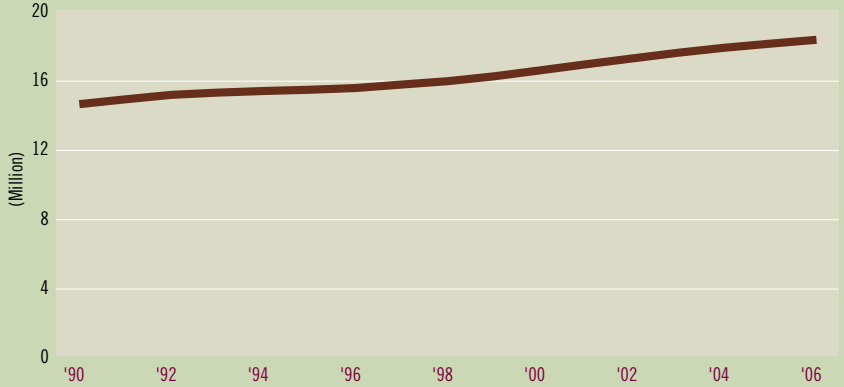
Many of us were not born in Southern California; we migrated here in search of opportunity, improved living conditions, and better lives. Southern California has its own connotation of lifestyle and perspective, and the allure of all that is available here has attracted millions who visit, vacation, or live, work, and raise their families here.

Steady increases in regional population have fueled dramatic regional changes, transitioning former agricultural areas into suburban communities, and converting dairy, grazing, and open land into large-footprint warehouses for redistribution of world imports (Figure 5). Population increases have also led to the need for more roads, more electrical power, more potable water, and more general services. Ultimately, this growth requires improved urban planning. As our communities have grown in number and size, we have become more aware that the available land and resources are not inexhaustible; we need to make better informed choices about how we use the increasingly limited resources we have.

At this intersection of population growth and land use, there are also interactions with public health, the economy, business expansion, and priorities. As our communities and businesses expand, as our freeways and roadways more effectively connect us from one point to another, we increasingly have to make choices about how to use a given parcel of land or location. Where do we build the new schools needed to educate

Figure 5

Population in the SCAG Region



** SCAG Region includes Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties*
Source: California Department of Finance

the next generation? What about recreational areas to encourage physical exercise and mental health? Where do we house current and newly-arriving residents? How do we balance the economic needs of a society juggling manufacturing, service, and agricultural components with "growing green" and maintaining a "healthy lifestyle"?

Regional Problems Require Regional Solutions

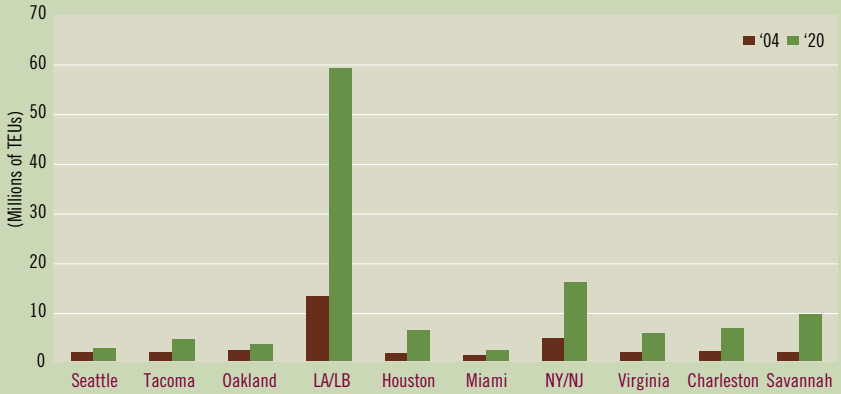
As a state, California has embraced and encouraged an expanded Goods Movement effort to accommodate international trade. The economic implications of such decisions are substantial, including a growing service sector economy, more jobs, and potentially lucrative funding opportunities. To achieve this Goods Movement vision, we are wrestling with the need for improved infrastructure – more cargo transfer terminals, more material re-distribution centers, more light and heavy duty vehicle-traveled freeways, more frequent and expanded rail operations, and more trucks. Each of these infrastructural expansions leads to more air pollution, unless we make some key critical choices very soon.

Local impacts are visual, visceral, and immediate. The communities of San Pedro, Wilmington, and Long Beach struggle with terminal expansion, increased hours of port operation, more trucks on the streets, more trains (and rail crossing delays), more noise and aesthetics issues, and more health concerns. The ports are wrestling with what they perceive as their mandate ("accommodate growth") and what they accept as their civil obligation (doing their "fair share" to clean up the air). But air emissions, like the millions of cargo boxes passing through the ports, don't stop at the port property's edge; they continue to move across the region. Similarly, the impacts of port operations reverberate across the region to downstream re-distribution centers, to so-called inland ports, and to communities east, north, and south of the port complex.

The decisions we make not only affect us here, but also affect the country at large, because we are the conduit for almost half of the country's imported cargo (see Figures 6 and 7). Our ports will almost surely continue to compete for larger portions of the national and

Figure 6

Volume of Trade to Major U.S. Ports



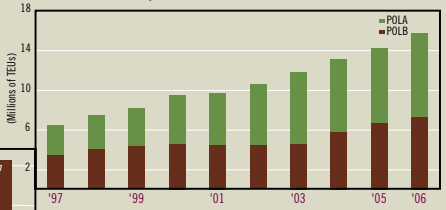
Source: U.S. Department of Transportation

Figure 7

Recent and Projected Port Growth within the South Coast Air Basin Area

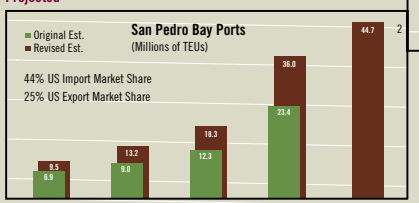
Container throughput is expected to triple in the next 15 to 20 years…

Actual San Pedro Bay TEU Growth



>100% since 1998…

Projected



Source: POLA, POLB and ACTA

international cargo transport pie. So while we grapple locally with the immediate impacts of increased infrastructural demands, and as the Goods Movement ramps up through our region, we need to be mindful that the entire country is betting that we will deliver.

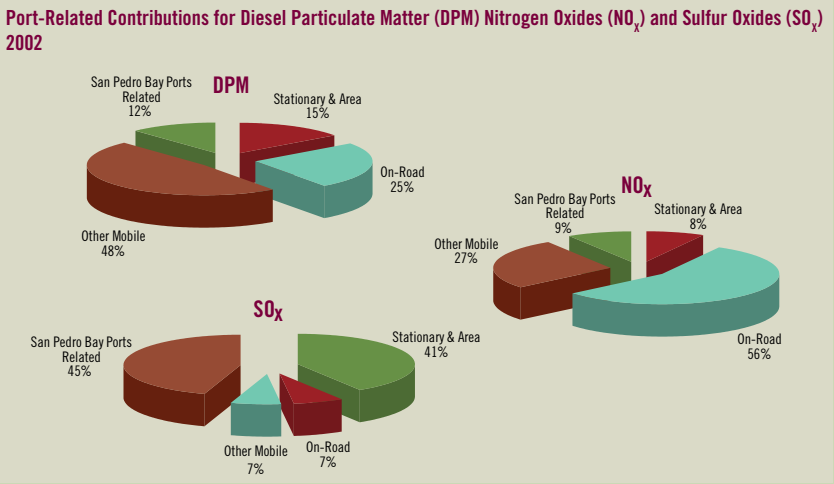
So what must we do to preserve and protect the health of our communities, yet respect our national obligations and role in providing international goods to the nation? Must we sacrifice local health to ensure economic vitality for the country?

The answer should be a resounding NO. We must push ahead on aggressive emission reduction strategies and emphasize at every turn that the public's health must be a part of the discussion. There must be an acknowledgement that human health concerns are paramount, that we cannot accept the ways of the past to be the methods of the future.

Some encouraging signs suggest an awakening may be underway. The ports of Los Angeles and Long Beach have entered into an historic agreement, to work together on a far-reaching and evolving Clean Air Action Plan (CAAP)[48]. The plan includes dozens of emission control measures, developed with the active participation of ports' staff and the regulatory air pollution control agencies (the local SCAQMD, the State's CARB, and the USEPA) and feedback from the community. An annual review of CAAP reduction strategies – both those that are working and not – and a continued ratcheting down of emissions are critical elements of the plan. Lease negotiations and port-wide tariffs to enforce emission reduction strategies will provide additional leverage for timely emissions reduction.

But the CAAP in its current form – or the CAAP, in any form – will not solve our regional air quality problems, even though port operations account for a substantial portion of daily regional pollution (Figure 8).

Figure 8



Mobile source pollution is our region's major air quality problem, and mobile sources are regulated by the State and Federal (not local or regional) governments. Inter-state or international transport (of goods, of people, and of pollution) fall under the jurisdiction of the federal government, or under multi-national control. So, state and federal agencies must do more, since their regulatory reach covers the vast majority of the pollution sources involved. Locally, we must continue to lobby for aggressive emission reduction strategies to accelerate the pace of cleanup.

What can we do locally to help? We begin in the ports of Long Beach and Los Angeles, collectively the largest source of air pollution in Southern California. In terms of mass emissions, ocean-going vessels contribute over half of the PM emissions in the port, 90% of the SOx (which is involved in atmospheric chemical reactions leading to downwind formation of PM) and over one-third of the NOx (which is

also important downwind, due to its involvement in chemical reactions leading to increased ozone and PM). Ships burn large amounts of relatively dirty, internationally purchased fuel, both in transit and in port. Regulatory control of ship emissions has been difficult, due to the international nature of ship operations and the cautious pace of activity (or inactivity) of port pollution control at the federal level.

Aggressive strategies to reduce the impurities in and amount of the fuels being consumed need to be pursued. Since January 2007, all ships visiting California ports are required to burn low-sulfur fuels in their auxiliary engines. The CAAP calls for the use of still-lower-sulfur fuels in the next several years. However, more could be done in a shorter period of time, by enforcing the use of 0.1% sulfur fuel in ship engines by 2010 (currently required by CARB by 2010 for ships' auxiliary engines only). Recently, a large terminal operator in the Los Angeles Port (Maersk) unilaterally changed to operating their ships on 0.2% fuel in the Los Angeles area, while others were still using fuel ten times dirtier and debating whether moves to cleaner fuel were feasible or safe. Progressive actions such as Maersk's needs to become the standard, rather than the rare example, for corporate operations to be welcomed in our region.

Electrification of port and rail operations and dramatically increased use of other clean-energy operations, rather than continued planned reliance on diesel-based engines and operations, needs to be expedited. Aggressive replacement of older, dirtier vehicles (from industrial trucks to commercial off-road bulldozers and yard equipment, to cars, buses, trains, and planes) needs to be emphasized. Getting older dirtier vehicles out of routine operations should be a high priority.

We need to move forward on alternative transportation modes for goods and people, to achieve both energy and emissions savings. New technologies and modes of transport must be evaluated and piloted. Existing mass transit operations need to be optimized, expanded, and improved. Fleet rules for cars and trucks need to updated and advanced to provide ever-cleaner options and access. The "hydrogen superhighway" or magnetic levitation may not be in our immediate future, but plug-in hybrids, liquefied natural gas (LNG) vehicles, enforcement of the best available engine control standards, and C-O-N-S-E-R-V-A-T-I-O-N are available now or in the very near future, and should be emphasized. Political inaction and inertia can no longer be tolerated.

Regional and state agencies have identified a number of possible emissions reduction measures and approaches. Their approaches are often promising, but the timing for enforcement and application has

often been viewed as "chaotically quick" by industry and "agonizingly slow" by the public. We need to move beyond the plodding sense of transitional change often ingrained in institutional operations and remember that pollution exposures are ongoing as we move ever so slowly along. Where health is an issue, we need to accelerate our actions.

Local government could and should take action to address air quality health impacts. General Plans could minimize land uses that increase air pollution-related health impacts from exposure to toxic air contaminants and particulates. Ever-enlightened approaches to land use and urban planning could be applied, because how we build our cities and infrastructure define how we will expend our resources in transit, operation, and production of services. Local governments need to plan for closer linkages in infrastructure - including on-dock rail for cargo transport, neighborhood schools for home-to-school commuting, shopping and business proximity to residential areas, and improved telecommuting and video-teleconferencing for workers. Such planning will require more regional perspectives, which could be an important contribution of regional organizations such as SCAG (who are already involved in numerous demonstration projects).

But planners and plans will not be successful without public endorsement and support. We need to develop more effective public outreach about the goals, methods, sacrifices, and costs involved in pollution reduction. These efforts should involve multi-media campaigns to publicize the actions underway, the need for those actions, and the progress being made as a result of those actions. All avenues should be explored, from television and radio public service announcements to on-screen movie-theatre ads, to internet notices, to fact sheets circulated at parks, schools, doctors' offices, and social organizations, to newspaper and magazine/journal articles. If we don't provide the public with clear and persuasive evidence for proposed changes or the benefits of choosing them, proposed changes will neither be publicly supported nor politically made.

Parting Thoughts

Southern California is a showcase for many positive attributes…and for some not-so-positive ones, as well. Regional air pollution, and the actions we take to respond to it, represents a singular opportunity for demonstrating what can be done if we commit our considerable resources and will to the task.

In the face of steady population increases and ever-expanding residential growth, the slow but steady improvement in air quality in Southern California is testimony to regulatory agency determination, focus, and accomplishment. Recent health research, however, provides evidence for concern about long-term health effects of exposure to air

pollutants, including respiratory symptoms, low lung function, low birth weight, cardiovascular disease progression, and death. The exposures and resulting health effects are occurring now, from the air that we all breathe, in the communities we all live in.

Current federal air quality standards require compliance in 7 years for $PM_{2.5}$ and 17 years for ozone. Waiting another 7 (or 17) years for this region to achieve air quality considered protective of public health effectively means the respiratory health of the current generation of children is being written off. That is a tragedy and should be justification enough for an emergency wake-up call, to apply all available technologies to clean up our air as quickly as possible.

If cleaning up the air we all breathe is more quickly achieved by declaring an emergency air quality/health crisis, then that decla-ration is justified, because the crisis exists now. We need to face these issues head-on, read the "handwriting on the wall" regarding the public health impacts of continued emissions, and mount an overwhelming and immediate effort to clean up our air. We do this for ourselves, for our children, and for our regional future...and we can no longer delay.

Ed Avol is Professor in the Keck School of Medicine at USC

References

1. Resolution #07-487-2 approving Appendix IV-C of the 2007 South Coast Air Quality Management Plan (AQMP) and urging the declaration of a state and federal emergency to address the Air Quality Health Crisis, May 3, 2007 Letter to the Regional Council,SCAG Energy and Environment Committee.
2. http://www.epa.gov/air/criteria.html.
3. http://www.arb.ca.gov/research/aaqs/no2-rs/no2-rs.htm.
4. http://www.arb.ca.gov/research/aaqs/ozone-rs/ozone-rs.htm.
5. http://www.epa.gov/air/ozonepollution/naaqsrev2007.html.
6. http://www.arb.ca.gov/research/aaqs/std-rs/std-rs.htm.
7. http://www.epa.gov/oar/particlepollution/standards.html.
8. http://www.epa.gov/sab/pdf/casac-07-001.pdf.
9. Draft 2007 Air Quality Management Plan, South Coast Air Quality Management District, March 2007.
10. Gauderman WJ, McConnell R, Gilliland F, London S, Thomas D, Avol E, Vora H, Berhane, K, Rappaport EB, Lurmann F, Margolis HG, Peters JM. Association between air pollution and lung function growth in Southern California children. Am J Resp Crit Care Med162:1383-1890, 2000.
11. Gauderman WJ, Gilliland F, Vora H, Avol E, Stram D, McConnell R, Thomas D, Lurmann F, Margolis H, Rappaport E, Berhane K, Peters J. Association between air pollution and lung function growth in Southern California children: results from a second cohort. Am J Respir Crit Care Med 2002; 166(1):76-84.
12. Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Künzli N, Lurmann F, Rappaport E, Margolia H, Bates D, Peters J. The effect of air pollution on lung function development in children aged 10 to 18 years. N Eng J Med 2004;351:1057-67.
13. McConnell R, Berhane K, Gilliland F, London SJ, Vora H, Avol E, Gauderman WJ, Margolis HG, Lurmann F, Thomas DC, Peters JM. Air pollution and bronchitic symptoms in Southern California children with asthma. Environ Health Perspect 107(9):757-760, 1999.
14. Kim JJ, Smorodinsky S, Lipsett M, Singer BC, Hodgson AT, Ostro B. Traffic-related air pollution near busy roads: the East Bay

Children's Respiratory Health Study. Am J Resp Crit Care Med 2004 Sept 1;170(5):520-6.

15. Brunekreef B, Janssen NA, de Hartog J, Harssema H, Knape M, van Vliet P. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology 1997 May;8(3): 298-303.

16. McConnell R, Berhane K, Gilliland F, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM. Asthma in exercising children exposed to ozone: a cohort study. Lancet 359(9304): 386-91, 2002.

17. Gilliland FD, Berhane K, Rappaport EB, Thomas DC, Avol E, Gauderman J, London SJ, Margolis HG, McConnell R, Islam KT, Peters, JM. The effects of ambient air pollution on school absenteeism due to respiratory llnesses.Epidemiol 12:43-54, 2001.

18. Hall J.V., Brajer V., and Lurmann F.W. (2003) Economic valuation of ozone-related school absences in the South Coast Air Basin of California. Contemporary Economic Policy, 21 (4), pp. 407-411.

19. Ashley F, Kannel WB, Sorlie P, Masson R Pulmonary function: relation to aging, cigarette habit, and mortality. The Framingham Study. An Int Med 1995; 82:739-45.

20. Bang KM, Gergen PJ, Kramer R, Cohen B. The effect of pulmonary impairment on all-cause mortality in a national cohort. Chest 1993;103:536-40.

21. Hole DJ, Watt CM, Davey-Smith G, Hart CL, Gillis CR, Hawthorne VM. Impaired lung function and mortality risk in men and women: findings from the Renfrew and Paisley prospective population study. BMJ 1996;313:711-15.

22. Ebi-Kryston KL. Respiratory symptoms and pulmonary function as predictors of 10-year motrality from respiratory disease, cardiovascular disease and all causes in the Whitehall study. J Clin Epidemiol 1988;41(3):251-60.

23. Gauderman WJ, Vora H, McConnell R, Berhane K, Gilliland F, Thomas D, Lurmann F, Avol E, Kunzli N, Jerrett M, Peters J. Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. Lancet 2007 Feb17;369(9561):571-7.

24. McConnell R, Berhane K, Yao L, Jerrett M, Lurmann F, Gilliland F, Kunzli N, Gauderman J, Avol E, Thomas D, Peters J. traffic, susceptibility, and childhood asthma. Environ Health Perspect 2006 May;114(5):766-72.

25. Wilhelm M, Ritz B. residential proximity to traffic and adverse birth outcomes in Los Angeles County, California, 1994-1996. Environ Health Perspect, 2003 Feb; 111(2):207-16.

26. Wilhelm M, Ritz B. Local variations in CO and particulate air pollution and adverse birth outcomes in Los Angeles County, California, USA. Environ Health Perspect 2005 Sep:113(9):1212-21.

27. Ritz B, Wilhelm M, Zhao Y. Air pollution and infant death in southern California, 1989-2000. Pediatrics, 2000 Aug:118(2):493-502.

28. Kuenzli N, Jerrett M, Mack WJ, Beckerman B, LaBree L, Gilliland F, Thomas D, Hodis HN. Ambient air pollution and atherosclerosis in Los Angeles. Environ Health Perspect, 2005 Frb:113(2):201-6.

29. Hoffman B, S Moebus, S Mohlenkamp, A Stang, N Lehman, D Dragano, A Schmermund, M Memmesheimer, K Mann, R Erbel, K-H Jockel, and for the Heinz Nixdorf Recall Study Investigative Group. 2007. Residential Exposure to Traffic is Associated with Coronary Atherosclerosis. Circulation published online July 16, 2007, DOI: 10.1161 / CIRCULATIONAHA.107693622.

30. Miller KA, Siscovick DS, Sheppard L, Shepherd K, Sullivan JH, Anderson GL, Kaufman JD. Long-term exposure to air pollution

and incidence of cardiovascular events in women. N Engl J Med 2007 Feb 1:356(5):447-58.

31. Li N, Sioutas C, Cho A, Schmitz D, Misra C, Sempf J, Wang M, Oberly T, Froines J, Nel A. Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage. Environ Health Perspect 2003 Apr; 111(4):455-60.

32. Elder A, Gelein R, Silva V, Feikert T, Opanashuk L, Carter J, Potter R, Maynard A, Ito Y, Finkelstein J, Oberdorster G. Translocation of inhaled ultrafine manganese oxide particles to the central nervous system. Environ Health Perspect 2006 Aug;114(8):1172-8.

33. Peters A, Veronesi B, Calderon-Garciduenas L, Gehr P, Chen LC, Geiser M, Reed W, Rothen-Rutishauser B, Schurch S, Schulz H. Translocation and potential neurological effects of fine and ultrafine particle: a critical update. Part Fibre Toxicol 2006 Sep 8;3-13.

34. Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. J Air Waste Manag Assoc 2006 Jun; 56(6):709-42.

35. Jerrett M, Burnett RT, Ma R, Pope CA, Krewski D, Newbold KB, Thurston G, Shi Y, Finkelstein N, Calle EE, Thun MJ. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology 2005 Nov:16(6):727-36.

36. Ostro BD, Tran H, Levy JI. The health benefits of reduced tropospheric ozone in California. J Air Waste Manag Assoc 2006, 2006 Jul:56(7):1007-21.

37. Ostro B, Feng WY, Broadwin R, Green S, Lipsett M. The effects of components of fine particulate air pollution on mortality in California: results from CALFINE. Environ Health Perspect 2007 Jan; 115(1):13-9.

38. Dominici F, McDermott A, Daniels M, Zeger SL, Samet JM. Revised analyses of the National Morbidity, Mortality, and Air Pollution Study: mortality among residents of 90 cities. J Toxicol Environ Health A 2005 Jul 9-23; 68(13-14:1071-92.

39. Sarnat JA, Schwartz J, Suh HH. Fine particulate air pollution and mortality in 20 US cities. N Engl J Med 2000 Dec 14:343(24):1742-9.

40. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US Urban Communities, 1987-2000. JAMA 2004;292:2372-2378.

41. Krewski D, Burnett R, Jerrett M, Pope CA, Rainham D, Calle E, Thurston G, Thun M. Mortality and long-term exposure to ambient air pollution: ongoing analyses based on the Amercian Cancer Society cohort. J Toxicol Environ Health A 2005 Jul 9-23;68 (13-14):1093-109.

42. Zhang Y, Huang W, London SJ, Song G, Chen G, Jiang L, Zhao N, Chen B, Kan H. Ozone and daily mortality in Shanghai China. Environ Health Perspect 2006 Aug;114(8):1227-32.

43. Hoek G, Schwartz JD, Groot B, Eilers P. Effects of ambient particulate matter and ozone on daily mortality in Rotterdam, the Netherlands. Arch Environ Health 1997 Nov-Dec;52(6):455-63.

44. Personal Communication, Richard Bode, California Air Resources Board.

45. Levy JI, Chemerynski SM, Sarnat JA. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology 2005 Jul; 16(4):458-68.

46. Schwartz J. How sensitive is the association between ozone and daily deaths to control for temperature? Am J Resp Crit Care Med 2005 Mar 15; 171(6):627-31.

47. Schwartz J. Is the association of airborne particles with daily deaths confounded by gaseous air pollutants? An approach to control by matching. Environ Health Perspect 2004 Apr; 112(5):557-61.

48. San Pedro Bay Ports Clean Air Action Plan, available at http://www.portoflosangeles.org/environment_air.htm.

Figures:

1. Maximum Pollutant Concentrations in the South Coast Air Basin Compared to Other U.S. Metro Areas, 2005 (courtesy of South Coast Air Quality Management District).
2. Maximum Pollutant Concentrations in the South Coast Air Basin (courtesy of the South Coast Air Quality Management District).
3. Ozone Trends in the South Coast Air Basin (courtesy of South Coast Air Quality Management District).
4. PM_{10} and $PM_{2.5}$ Trends in the South Coast Air Basin (courtesy of South Coast Air Quality Management District).
5. Population in the SCAG Region.
6. Volume of Trade to Major U.S. Ports (from U.S. Dept of Transportation data).
7. Recent and Projected Port Growth within the South Coast Air Basin Area (ports of Los Angeles and Long Beach).
8. Port-related Contributions for Diesel Particulate Matter (DPM), Nitrogen Oxides (NO_X), and Sulfur Oxides (SO_X) (courtesy of Port of Los Angeles).